Stable Carbon Isotopic Composition of Redheads on their Breeding and Wintering Ranges

Photo Courtesy of Rick Warhurst, Ducks Unlimited, Inc.

Marc C. Woodin
U.S. Geological Survey
Columbia Environmental Research Center
Texas Gulf Coast Field Research Station
Corpus Christi, TX
361.985.6266
marc_woodin@usgs.gov

Beth Trust Hammer
University of Texas Marine Science Institute
Port Aransas, TX

ABSTRACT

We investigated $\delta^{13}C$ values of breast and leg muscle, liver, gizzard, and abdominal fat from 259 Redheads obtained from the Texas winter range, South Dakota breeding grounds, and from a molting lake in Manitoba. We also measured $\delta^{13}C$ values of representative aquatic biota, including known Redhead foods, from these areas. We tested the hypothesis that, as Redheads change from a seagrass diet in winter, to a mixed diet while breeding, and then to a postbreeding diet of submerged aquatic vegetation, the isotopic composition of their tissues will change also. Tissue $\delta^{13}C$ values, which were highest for winter birds (range = -10.0 to -13.1 ppt) and lowest for breeding birds (range = -22.4 to -28.7 ppt), changed seasonally to reflect altered isotopic composition of diets.

INTRODUCTION

Q. What Are Stable Isotopes?

A. Stable isotopes are naturally occurring, nonradioactive forms of the same chemical element. Although stable isotopes of an element possess the same atomic number, they have different atomic weights by virtue of the variable number of neutrons in their nuclei. While stable isotopes react identically chemically, different rates of reaction result in natural variation in isotopic composition.

Q. Which Elements Occur as Isotopes?

A. Many elements possess two or more isotopic forms. These six elements have been used most frequently in ecological studies.

Carbon (^{12}C and ^{13}C)	Nitrogen (^{14}N and ^{15}N)
Hydrogen (^{1}H and ^{2}H)	Oxygen (^{16}O and ^{17}O)
Sulfur (^{32}S, ^{33}S, ^{34}S, and ^{36}S)	Strontium (^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr)

Q. How Are Stable Isotopes Used in Ecology?

A. Since stable isotopes do not decay over time as radioactive isotopes do, stable isotopic composition serves as a natural marker. Stable isotopes are used as markers to trace substances in studies of foraging ecology and food webs, nutrient and energy flow, tissue turnover rates, habitat use, geographical distribution, and origin of pollutants. An overview of stable isotopes in ecological research is provided in Rundel et al. (1988).

Q. What Advantages Are Offered by Use of Stable Isotopes in Foraging Ecology Studies?

A.

1) Isotopic ratios provide long-term dietary information through time.
2) Isotopic composition indicates what was assimilated, rather than what was ingested.
3) Dietary components can be determined even though identifiable foods may be absent from the digestive system.

Q. Why Is the Redhead a Prime Species for an Isotope Ecology Study?

A.

1) The route (Figure 1) and timing of migration are well known.
2) Important aspects of Redhead biology and habitats are well known for the breeding range in the prairie pothole region, postbreeding lakes, and the major winter range (Figure 2).
3) Foods consumed at different stages during the annual life cycle are well documented for the prairie pothole breeding range, postbreeding lakes, and the winter range in Texas.

Q. Why Are Carbon Isotopes So Useful in Foraging Ecology Studies?

A. Carbon isotopic composition of animal tissues is determined primarily by isotopic composition of the diet. When organisms switch diet, carbon isotopes may be used to study foraging, nutrient assimilation, or carbon turnover in tissues. This opportunity is enhanced if the diet switch exposes animals to distinctly different carbon signals.

OBJECTIVES

1) Compare carbon isotopic composition of tissues of Redheads from different stages of their annual life cycle.
2) Compare isotopic composition of Redhead foods from wintering, breeding, and postbreeding habitats with changes in isotopic composition of tissues of Redheads.

METHODS

1) A total of 216 Redheads from coastal Texas, 31 breeding birds from South Dakota, and 12 postbreeding Redheads from Lake Winnipegosis were available from other studies.
2) Samples of the following tissues from each of these birds were removed for isotopic analyses: leg muscle, breast muscle, gizzard, liver, and abdominal fat.
3) Roots, rhizomes, and leaves of seagrasses were collected from Redfish Bay and the upper Laguna Madre, Texas. Aquatic plants and invertebrates were collected from representative prairie wetlands in northeastern South Dakota. All plants and invertebrates were ground before isotopic analysis.
4) All samples of duck tissues, plants, and animals were analyzed for stable carbon isotope ratio according to the sealed-tube method of Sofer (1980).
5) All carbon isotopic ratios are expressed by the conventional delta (δ) notation,

$$\delta^{13}C\ (\text{ppt}) = [(R_{sample}/R_{standard}) - 1] \times 1000$$

where R_{sample} and $R_{standard}$ are the $^{13}C/^{12}C$ isotopic ratios of the sample and standard, respectively (Craig 1957). Reproducibility of the carbon isotope measurement was 0.2 ppt.

CONCLUSIONS

1) Tissues of Redheads from the winter range (fall and winter) in Texas reflect more positive values of $\delta^{13}C$ derived from shoalgrass (Tables 1 and 2). This becomes most pronounced for birds that have been in Texas for ≥2 months (winter in Table 1).
2) Tissues of Redheads from the breeding range show sharply more negative values of $\delta^{13}C$ (Table 1), reflecting the carbon signature of foods from prairie wetlands in South Dakota (Table 2). The strong signature of seagrass carbon present in birds when they depart Texas cannot be detected when Redheads arrive in May on the breeding range.
3) Isotopic composition of tissues of postbreeding Redheads from Lake Winnipegosis is intermediate between that of breeding Redheads and birds in winter. These values probably reflect mostly the local carbon signature of *Chara* spp., which can vary widely (-15 to -30 ppt).
4) Significant differences between males and females in $\delta^{13}C$ values of tissues of postbreeding and fall birds (Table 1) are most likely a consequence of differential migration habits.
5) The extremely close correlation of isotopic compositions of breast and leg muscle indicates that carbon turnover in these two tissues occurs at similar rates.

LITERATURE CITED

Bellrose, F.C. 1980. *Ducks, Geese, and Swans of North America*. Stackpole Books, Harrisburg, PA.

Craig, H. 1957. Isotopic Standards for Carbon and Oxygen and Correction Factors for Mass-Spectrometric Analysis of Carbon Dioxide. *Geochimica et Cosmochimica Acta* 12:133-149.

Rundel, P.W., J.R. Ehleringer, and K.A. Nagy, editors. 1988. Stable Isotopes in Ecological Research. *Ecological Studies* (vol. 68). Springer-Verlag, New York.

Sofer, Z. 1980. Preparation of Carbon Dioxide for Stable Carbon Isotope Analysis of Petroleum Fractions. *Analytical Chemistry* 52:1389-1391.

Trust, B.A. 1993. Stable Carbon and Sulfur Isotopic Ratios in Migrating Redhead ducks (Aythya americana) and their breeding and wintering habitats. Ph.D. diss., Univ. of Texas.

Woodin, M.C. 1996. Wintering Ecology of Redheads (*Aythya americana*) in the Western Gulf of Mexico Region. *Gibier Fuane Sauvage* (Game and Wildlife) 13:653-665.

PHOTOS

Redhead Foods from the Laguna Madre

Waterfowl Foods from Prairie Wetlands

Redhead Flock on the Laguna Madre

Wetlands – Prairie Pothole Region

TABLES

Tissue	Sex	Season			
		Fall	Winter	Breeding	Postbreeding
Breast Muscle	M	-15.1[a] ± 3.3 (64)	-11.4 [c] ± 1.4 (73)	-22.5 [d] ± 2.6 (8)	-15.3 [a,b] ± 2.5 (7)
	F	-17.6 [b,e] ± 3.9 (32)	-11.5 [c] ± 1.4 (41)	-22.4 [d] ± 2.8 (23)	-20.7 [d,e] ± 3.3 (5)
Leg Muscle	M	-14.6 [a] ± 3.0 (68)	-11.2 [c] ± 1.2 (73)	-23.1 [d] ± 2.6 (9)	-14.6 [a,b] ± 2.7 (7)
	F	-17.0 [b] ± 3.6 (32)	-11.6 [c] ± 1.2 (42)	-22.7 [d] ± 2.9 (22)	-20.1 [d] ± 2.4 (5)
Liver	M	-12.5 [a] ± 2.2 (66)	-10.4 [c] ± 1.3 (75)	-27.1 [d] ± 2.8 (8)	-12.8 [a,b] ± 1.5 (7)
	F	-14.0 [b] ± 2.9 (30)	-10.5 [c] ± 1.2 (41)	-27.0 [d] ± 3.0 (21)	-16.6 ± 2.3 (5)
Gizzard	M	-13.0 [a] ± 2.6 (65)	-10.0 [c] ± 1.2 (74)	-23.9 [d] ± 2.7 (7)	-14.1 [a,b] ± 2.5 (7)
	F	-15.0 [b] ± 3.1 (31)	-10.0 [c] ± 1.2 (41)	-23.6 [d] ± 2.8 (23)	-18.8 ± 2.2 (5)
Abdominal Fat	M	-15.3 [a,e] ± 2.8 (65)	-12.9 [c] ± 1.3 (73)	-28.7 [d] ± 6.5 (8)	-13.5 [a,c,f] ± 2.0 (7)
	F	-17.8 [b] ± 4.7 (31)	-13.1 [c] ± 1.4 (39)	-28.2 [d] ± 6.2 (22)	-17.0 [b,e,f] ± 3.1 (5)

Table 1. Mean δ^{13}C values (ppt) (± 1 standard deviation) and sample sizes of tissues analyzed from Redheads in fall (Nov. – Dec. 1988 and 1989, Texas), winter (Jan. – Mar. 1989 and 1990, Texas), breeding (May 1990, South Dakota), and postbreeding (Sept. 1990, Manitoba) seasons. Means within each tissue type denoted with identical letters are not significantly (P<0.01) different. If no letter is denoted, then the mean is significantly different from all other values. M = Male; F = Female.

Table 2. $\delta^{13}C$ values (ppt) of Redhead food items (from Trust 1993).

Food Item	Location	$\delta^{13}C \pm 1$ s.d. (*n*)
Halodule wrightii	TX	-10.1 ± 1.0 (6)
Scirpus spp.	SD	-26.4 ± 1.2 (7)
Beckmannia syzigachne	SD	-28.5 (1)
Polygonum spp.	SD	-26.0 ± 2.1 (2)
Potamogeton spp.	SD	-17.2 ± 3.8 (4)
Cladocera	SD	-27.8 (1)
Lymnaeid Snails	SD	-26.6 ± 1.9 (5)
Chironomidae	SD	-28.0 ± 3.4 (4)
Odonate Nymphs	SD	-28.1 ± 0.5 (2)

FIGURES

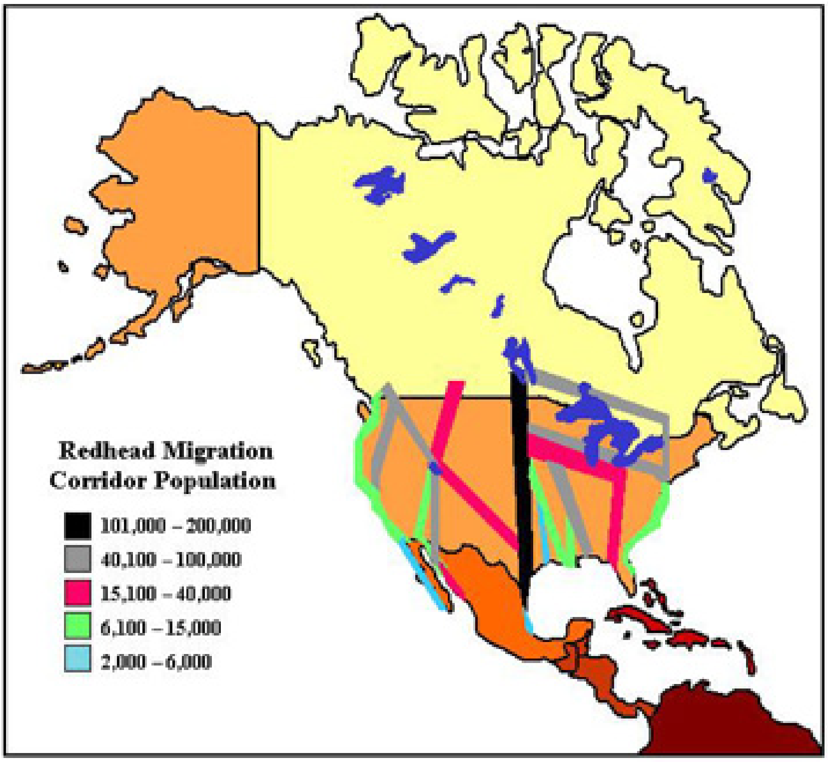

Figure 1. Migration patterns for the continental population of Redheads (adapted from Bellrose 1980).

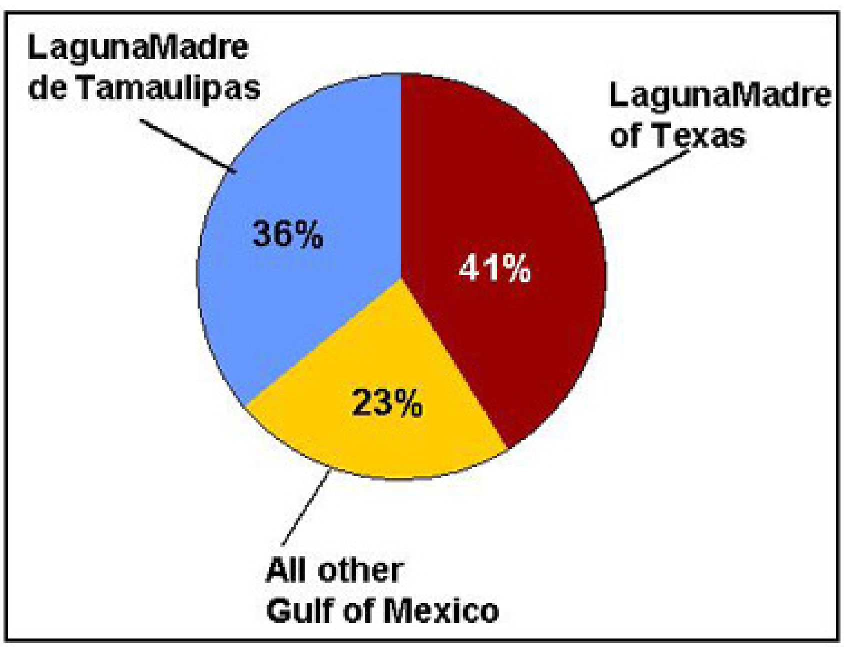

Figure 2. Mean percentages of Redheads wintering on Laguna Madre of Texas and Laguna Madre of Tamaulipas, compared with all other Gulf of Mexico birds combined, 1980-1994 (Woodin 1996).

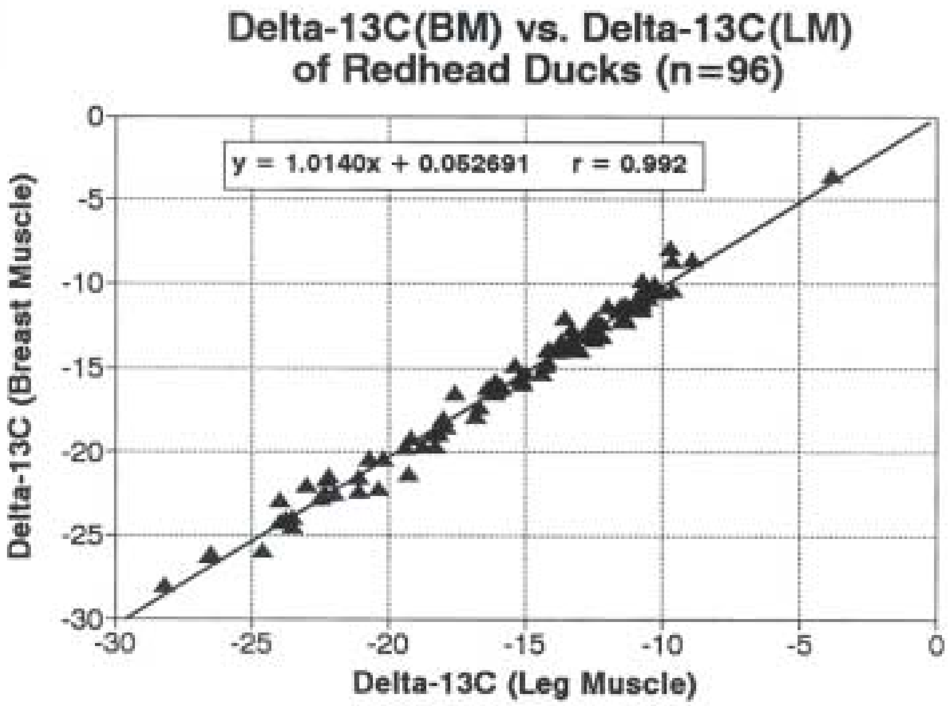

Figure 3. The $\delta\,^{13}C$ value of breast muscle vs. the $\delta\,^{13}C$ value of leg muscle for Redheads (Trust 1993).